

WHAT IS CLAIMED IS:

1 1. A method for forming an optical waveguide on a substrate in a
2 process chamber, the method comprising:
3 depositing an undercladding layer over the substrate;
4 forming at least one core over the undercladding layer; and
5 depositing an uppercladding layer over the at least one core with a high-
6 density plasma process.

1 2. The method recited in claim 1 wherein depositing the
2 uppercladding layer comprises:
3 flowing an oxygen-containing gas and a silicon-containing gas into the
4 process chamber to produce a gaseous mixture;
5 generating a high-density plasma from the gaseous mixture; and
6 depositing a silicate glass layer over the at least one core with the high-
7 density plasma.

1 3. The method recited in claim 2 wherein a flow rate of the oxygen-
2 containing gas is more than 1.8 times a flow rate of the silicon-containing gas.

1 4. The method recited in claim 3 wherein the flow rate of the
2 oxygen-containing gas is greater than 175 sccm and the flow rate of the silicon
3 containing gas is between 80 and 110 sccm.

1 5. The method recited in claim 4 wherein the oxygen-containing
2 gas comprises O₂ and the silicon-containing gas comprises SiH₄.

1 6. The method recited in claim 2 wherein depositing the
2 uppercladding layer further comprises flowing an inert gas into the process chamber
3 with a flow rate between 0 and 200 sccm.

1 7. The method recited in claim 2 wherein depositing the
2 uppercladding layer further comprises flowing a fluorine-containing gas into the
3 process chamber with a flow rate between 10 and 20 sccm.

1 8. The method recited in claim 7 wherein the fluorine-containing
2 gas comprises SiF₄.

1 9. The method recited in claim 2 wherein depositing the
2 uppercladding layer further comprises flowing a phosphorus-containing gas into the
3 process chamber with a flow rate between 0 and 30 sccm.

1 10. The method recited in claim 9 wherein the phosphorus-
2 containing gas comprises PH₃.

1 11. The method recited in claim 2 wherein depositing the
2 uppercladding layer further comprises flowing a boron-containing gas into the process
3 chamber with a flow rate between 0 and 20 sccm.

1 12. The method recited in claim 11 wherein the boron-containing gas
2 comprises BF₃.

1 13. The method recited in claim 2 further comprising applying an RF
2 source power to the process chamber, the RF source power having a power density
3 between 6 and 30 W/cm².

1 14. The method recited in claim 2 further comprising applying an RF
2 bias power to the substrate, the RF bias power having a power density between 0 and
3 16 W/cm².

1 15. The method recited in claim 2 wherein depositing the silicate
2 glass layer comprises depositing the silicate glass layer at a pressure less than 12 mtorr.

1 16. The method recited in claim 1 wherein depositing the
2 uppercladding layer comprises:

3 flowing O₂ into the process chamber with a flow rate greater than 175
4 sccm;

5 flowing SiH₄ into the process chamber with a flow rate between 80 and
6 110 sccm such that a ratio of the O₂ flow rate to the SiH₄ flow rate is greater than 1.8;

7 flowing SiF₄ into the process chamber with a flow rate between 10 and
8 20 sccm;

9 flowing Ar into the process chamber with a flow rate between 0 and 200
10 sccm;

11 generating a high-density plasma from the gases flowed into the process
12 chamber; and

13 applying an RF bias power to the substrate, the RF bias power having a
14 power density between 0 and 16 W/cm².

1 17. The method recited in claim 1 wherein forming at least one core
2 over the undercladding layer comprises forming a plurality of cores over the
3 undercladding layer, the method further comprising:

4 etching a portion of the uppercladding layer in gaps between the
5 plurality of cores; and

6 depositing a second uppercladding layer over the etched undercladding
7 layer.

1 18. The method recited in claim 1 wherein the high-density plasma
2 process comprises a high-density plasma electron-cyclotron-resonance process.

1 19. The method recited in claim 1 further comprising depositing a
2 second uppercladding layer over the uppercladding layer with a plasma-enhanced
3 chemical-vapor deposition process.

1 20. The method recited in claim 1 wherein the uppercladding layer
2 has a refractive index between about 1.4443 and 1.4473 at a wavelength of 1550 nm.

1 21. An optical waveguide made according to the method recited in
2 claim 20.

1 22. An optical waveguide made according to the method recited in
2 claim 1.

1 23. A method for forming an optical waveguide on a substrate in a
2 process chamber, the method comprising:

3 depositing an undercladding layer over the substrate;

4 forming at least one core over the undercladding layer;

5 depositing an uppercladding layer over the at least one core using a
6 high-density plasma CVD process; and

thereafter, completing formation of the optical waveguide without
thermally annealing the uppercladding layer.

1 24. The method recited in claim 23 wherein the uppercladding layer
2 comprises a fluorinated silicate glass layer.

1 25. A computer-readable storage medium having a computer-
2 readable program embodied therein for directing operation of a substrate processing
3 system including a process chamber; a plasma generation system; a substrate holder;
4 and a gas delivery system configured to introduce gases into the process chamber, the
5 computer-readable program including instructions for operating the substrate
6 processing system to form an optical waveguide on a substrate disposed in the
7 processing chamber in accordance with the following:

8 depositing an undercladding layer over the substrate;
9 forming at least one core over the undercladding layer;
10 flowing an oxygen-containing gas, a silicon-containing gas, and a
11 fluorine-containing gas into the process chamber to produce a gaseous mixture;
12 generating a high-density plasma from the gaseous mixture; and
13 depositing a fluorinated silicate glass uppercladding layer over the at
14 least one core.

1 26. The computer-readable storage medium recited in claim 25
2 wherein a flow rate of the oxygen-containing gas is at least 1.8 times as large as a flow
3 rate of the silicon-containing gas.

1 27. A substrate processing system comprising:
2 a housing defining a process chamber;
3 a high-density plasma generating system operatively coupled to the
4 process chamber;
5 a substrate holder configured to hold a substrate during substrate
6 processing;
7 a gas-delivery system configured to introduce gases into the process
8 chamber, including sources for a silicon-containing gas, a fluorine-containing gas, and
9 an oxygen-containing gas;

10 a pressure-control system for maintaining a selected pressure within the
11 process chamber;

12 a controller for controlling the high-density plasma generating system,
13 the gas-delivery system, and the pressure-control system; and

14 a memory coupled to the controller, the memory comprising a computer-
15 readable medium having a computer-readable program embodied therein for directing
16 operation of the substrate processing system to form an optical waveguide on a
17 substrate, the computer-readable program including

18 instructions to deposit an undercladding layer over the substrate;
19 instructions to form at least one core over the undercladding
20 layer;

21 instructions to flow a gaseous mixture containing flows of the
22 silicon-containing gas, the fluorine-containing gas, the nitrogen-containing gas, and the
23 oxygen-containing gas;

24 instructions to generate a high-density plasma from the gaseous
25 mixture and to apply a bias to the substrate; and

26 instructions to deposit a fluorinated silicate glass layer onto the
27 substrate using the high-density plasma.

1 28. The substrate processing system recited in claim 27 wherein a
2 flow rate of the oxygen-containing gas is at least 1.8 times as large as a flow rate of the
3 silicon-containing gas.